original sources and maxima of deposits—shortening the radii of areas of violent variations, and even of nonconformability—and embarrassing the best laid plans for restoring the state of things in ancient days.

Photodynamics. By Pliny Earle Chase, LL.D.

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The general laws of motion have been largely studied in connection with the special departments of Thermodynamics and Electrodynamics. Little attention has been paid, comparatively speaking, to the much broader field of Photodynamics.

Sir John Herschel showed* that the elastic force of the air, in its resistance to compression, would require to be increased, "*in proportion to the inertia of its molecules*," more than 1,000,000,000,000 fold to admit of the propagation of a wave with the velocity of light, and that this enormous physical force is perpetually exerted at every point, through all the immensity of space. He also said†: "It must be remembered that it is LIGHT, *and the free communication of it from the remotest region of the universe*, which alone can give and does give us the assurance of a uniform and all pervading energy." We have no equally positive evidence of the direct transmission of heat and electricity from the heavenly bodies, and inasmuch as all thermal and electrical phenomena can be explained by local transformations of simple radiant energy, the philosophical basis of Photodynamics appears to be better grounded than that of either Thermodynamics or Electrodynamics.

In 1863, I began a series of general kinetic investigations, in confirmation of views which may be expressed by the following general postulate: *All physical phenomena are due to an Omnipresent Power, acting in ways which may be represented by harmonic or cyclical undulations in an elastic medium.* In my first paper‡ I showed the importance of the fundamental equations $v = \frac{gt}{2}$; $h = \frac{gt^2}{4}$ = the *modulus* of v; in which t represents the time of cosmical, molecular, or atomic rotation, and g represents the acceleration of a central force.

By combining these equations with considerations derived from the equality of elastic actions and reactions proportioned to mass, and from tendencies to conservation of areas, I found that the daily and annual fluctuations of the barometer furnish harmonic indications of Sun's mass and distance, and I announced my confident expectation of other astronomical

* Familiar Lectures on Scientific Subjects, pp. 281-3

† Ib. p. 218.

‡ Proc. Am. Phil. Soc., vol. ix, pp. 283-8.

verifications or rectifications by means of varying pressures.* In the following year I introduced the hypothesis, which has since been largely developed by Edlund, that electricity consists simply of æthereal vibrations.† In confirmation of this hypothesis, I showed that many of the phenomena of terrestrial magnetism can be produced by simple mechanical vibrations, resembling those of the atmospheric currents which arise from the combined action of terrestrial rotation and thermal convection.‡ In connection with these investigations I called attention to the importance, and some of the probable consequences, of radial and tangential oscillations *moving with the rapidity of light*,§ and of their bearing upon "the phenomena of light, heat, electricity, polarity, aggregation, diffusion, meteorological changes, seismic tremors, crystallization, stratification, chemical action and general morphology."‖

My discovery of numerous numerical relations between gravity and magnetism, for which the American Philosophical Society awarded its Magellanic medal, led me to seek, in the maximum manifestations of gravitating force, the correlation of gravity with other forms of energy, for which Faraday** had looked confidently but in vain. The greatest gravitating force in our system and, therefore, the greatest of which we have any direct and positive evidence, is at Sun's surface, where material particles are subjected to such oscillations as may arise from the conflicting centripetal energies of solar attraction and of the resultant attraction of all other cosmical bodies. In applying the fundamental equation, $v = \frac{gt}{2}$, at Sun's surface or the locus of maximum gravitation, I found that the equality of action and reaction, as shown by the sum of the solar-central gravitating reactions against the sum of the gravitating actions towards the centre of the solar system, in the cyclically alternating thrusts and pulls of half-rotation, *is represented by the velocity of light.*†† This discovery, together with the identification of the same velocity as a factor of electro-magnetic action, which was completed and confirmed by the investigations of Thomson and Maxwell, brought all physical phenomena, cosmical as well as molecular, within the domain of Photodynamics.

The molecular phenomena may be readily connected with the cosmical, through the correspondence between Challis's laws of molecular action and the laws of attraction and rotation.‡‡ They furnish grounds for estimating Sun's mass and distance by means of the explosive energy of hydrogen ;§§ for discovering some of the subordinate elements of planetary arrange-

*Ib. ix, 288; x, 376.
†Ib. ix, 355-60.
‡Ib. ix, 367-71, 425-40, 487-95; x, 97-118, 151-66.
§Ib. ix, 405-11.
‖Ib. ix, 439.
**Exp. Res., 2614.
††Proc. Am. Phil. Soc., xi, 103-7.
‡‡Ib. ix, 367-71.
§§Ib. xii, 392-4.

ment ;* for a mathematical deduction of the ratio (1.4232) between the mean *vis viva* of gaseous volume (*heat under constant volume*) and the *vis viva* of uniform velocity (*heat under constant pressure*) ;† for finding an identity of law in luminous and planetary nodes ;‡ for a cosmical determination of Joule's equivalent ;§ and for connecting the molecular velocities of gaseous particles with the velocities of terrestrial rotation and revolution.‖

Although many of the stellar motions indicate the probability of gravitating action, in other systems than our own and between different systems, no direct, positive and measurable evidence of such action has yet been found. Gravitating and elastic forces may, however, be numerically compared, through the common equation of wave and orbital velocity, $v = \sqrt{2gh}$, in which h represents the height of virtual fall which would give the required velocity, or $\frac{1}{2}$ the height of a homogeneous atmosphere, or $\frac{1}{2}$ the radius of a circular orbit, or the focal distance in a parabolic orbit. In consequence of the tendency of nodal points, in any vibrating elastic medium, to produce harmonic vibrations and harmonic nodes of various kinds, we may reasonably look for such nodes as results and evidences of interstellar action.

Among the various gravitating, paraboloidal and harmonic wave influences, which have been instrumental in world building, the following seem specially noteworthy :

a. The principal centre of nucleation in the solar system, which is represented by the Sun.

β. The principal centre of condensation, which is represented by the Earth ; Mercury's secular perihelion being .2974,¶ and the secular aphelion of Mars being 1.73648, the middle of the dense belt of planets is 1.01694, which is midway between Earth's mean distance and mean aphelion (1.03387).

γ. The principal nebular centre of the system, which is represented by Jupiter's mean aphelion ; Neptune, the aphelion planet, being 30.03386, and Uranus, its corresponding perihelion planet, being 19.18358, the nebular centre is 5.42514. Jupiter's mean aphelion is 5.42735.

δ. The linear centre of oscillation of a solar diameter ($\frac{2}{5}$), which gives $\frac{1}{5}$ radius as a directrix of paraboloidal influence, and $\frac{1}{6}$ radius as the abscissa of the paraboloidal vertex.

ε. The ratio $(\frac{1}{3})^2$, between the solar central force at the paraboloidal vertex and the corresponding force at Sun's equatorial surface.

ζ. The ratio of dissociative subsidence $\left(\frac{nr}{n+1}\right)$. If we take the radius of a nebula as a fundamental node, the velocity which would be acquired

* Ib. xii, 403, seq.
† Ib. xiv, 651.
‡ Ib. xvii, 109-12.
§ Ib. xviii, 20-1.
‖ Ib. xviii, 21-5.
¶ The values are taken from Stockwell, *Smithsonian Contributions*, 232.

by a body in falling from a distance nr to any other distance x may be found by the equation, $vdv = gr^2x^{-2}d\ (nr-x)$; integrating and reducing, $v = \left\{\frac{2\,gr\,(nr-x)}{nx}\right\}^{\frac{1}{2}}$. If this velocity is due to a synchronism of activity, between nebular condensation within any given stellar system and parabolic projection between dfferent systems, $v = \sqrt{2gr}$; $\frac{nr-x}{nx} = 1$; $x = \frac{nr}{n+1}$.

η. If $n = 2$, $\frac{n}{n+1} = \frac{2}{3}$. This corresponds with the centre of linear oscillation; it is also the locus of belt formation, on account of the collision of subsiding particles from opposite extremities of a nebular diameter. In such subsidence there would be a tendency to form confocal elliptic orbits,* with major axes of $\frac{3r}{2}$ and minor axes of $r\sqrt{2}$.

θ. In rupturing or explosive oscillation, the *vis viva* of wave propagation is $\frac{5}{9}$ of the *vis viva* of oscillating particles.† This relation was subsequently pointed out by Maxwell,‡ apparently without being aware that I had called attention to it five years previously.

I. Harmonic nodes with the ratio $\frac{1}{9}$, (ε), indicate the primary division of the solar system, as may be seen by the following comparisons, in which r_0 represents Sun's radius:

Theoretical.		Observed.	
$9^2\ r_0 =$	$81\ r_0$	Mercury	$83.05\ r_0$
$9^3\ r_0 =$	$729\ r_0$	Asteroid 76	$731.37\ r_0$
$9^4\ r_0 =$	$6551\ r_0$	Neptune, s. a.§	$6536.91\ r_0$

II. The influence of subsidence (η), at the outer surfaces of the two primitive belts, is shown as follows:

Theoretical.		Observed.	
$\frac{2}{3}$ Neptune =	20.0226	Uranus, m. a.,	20.0442
$\frac{2}{3}$ Mars =	1.0158	Earth, m. a.,	1.0339

We have already seen, (β), that the middle of the belt of greatest condensation is 1.0169.

III. The influence of rupturing oscillation, (θ), at the inner surfaces of the two primitive belts, is equally evident.

Theoretical.		Observed.	
$\frac{2}{5}$ Mercury =	.696778	Venus, m. p.,	.696779
$\frac{2}{5}$ Jupiter =	9.3650	Saturn	9.5389

The oscillating limits of all portions of the Jupiter belt are within the Saturnian belt.

* Proc. Am. Phil. Soc., xvii, 98-109.
† Ib. xii, 392-4.
‡ See Phil. Mag., June, 1877, p. 453.
§ s., *secular*; a., *aphelion*; m., *mean*; p., *perhelion*.

IV. The influence of paraboloidal directrices and vertices, (δ), is manifested in each of the primitive belts :

$\frac{1}{6}$ Mars = .2894	Mercury s. p. .2974
$\frac{1}{6}$ Neptune = 5.0068	Jupiter m. p. 4.9782
$\frac{1}{3}$ Neptune = 10.01128	Saturn m. a. 10.00006

The paraboloidal vertex for the whole Neptunian belt is within the Jupiter belt.

V. By introducing Laplace's limit of possible solar atmosphere* ($L = 36.36r_0$), and the ratio, $\left(\frac{\pi}{\sqrt{2}}\right)$, of the fundamental velocity $\left(\frac{gt}{2}\right)$ to the corresponding parabolic velocity $\left(\frac{gt}{\pi\sqrt{2}}\right)$, we find the following simple equation of solar and planetary harmonic action at the centre of principal condensation. $\left(\frac{1 \text{ year}}{1 \text{ day}} \times \frac{\text{Sun's semi-diameter}}{\text{Earth's semi-axis major}}\right)^3 = \frac{\pi^2}{2}$. This gives Earth's semi-axis-major $= 214.54r_0$.

VI. The combined influence of centres of nucleation, (α), and of nebulosity, (β), at the centre of condensation, (γ), leads to the following simple harmonic estimate of Sun's mass and distance.

Earth's semi-axis major being $214.54r_0$, the leverage of the paraboloidal directrix is $(214.54 + \frac{1}{3} =) 214.87r_0$, and the mean leverage of Jupiter is $(5.202798 - 1) \times 214.54r_0 = 901.668283r_0$. Multiplying by the respective masses, we obtain, for the ratio of Sun's comparative disturbing force at the directrix and at the centre of condensation, $\frac{1047.879 \times 214.87}{1 \times 901.668283} = 249.712$. The superficial nodal force (ε) being $\frac{1}{9}$ as great, we find, for the ratio of Sun's to Earth's superficial gravity, $\frac{g_0}{g_1} = \frac{249.712}{9} = 27.716$. If we designate superficial gravity by g, volume by V, density by d, and mass by m, it is evident that $r \propto (g \div d)$; $V \propto (g \div d)^3$; $m \propto (g^3 \div d^2)$; $d \propto (g \div r)$. Hence we readily get $\frac{d_0}{d_1} = .25523$; $\frac{m_0}{m_1} = \left(\frac{27.716}{.25523}\right)^3 = 327{,}897$; $\frac{r_0}{r_1} = \frac{27.716}{.25523} = 108.71$; Earth's semi-axis major $= 214.54r_0 = 214.54 \times 108.71 \times 3962.8$ miles $= 92{,}422{,}000$ miles.

VII. The solar modulus of light, ($M = 688.82^2 r_0$), furnishes the third element of the parabolic projection which is indicated by the fundamental equation $v = \frac{gt}{2}$. The three elements are all photodynamic, viz: 1. The locus (r_0) of luminous action which makes $\frac{gt}{2}$ equivalent to the velocity of light; 2. The locus (L) of orbital half-revolution which is synchronous with solar half-rotation, the synchronic time being determined by the velocity of light; 3. The locus (M) of radial luminous progression during the same synchronic time of solar half-rotation; M is also the altitude, in

* *Mec. Cel.*, III, § 47.

the fundamental equation $h = \frac{gt^2}{4}$, of Sun's homogeneous æthereal, or light-propagating atmosphere. The values of L and M are found as follows:

The mean time of light-propagation from Sun to Earth being 497.827 seconds, the velocity of light $\left(v_\lambda\right)$ is $214.54r_0 \div 497.827 = .43095r_0$; $v_0 = \sqrt{g_0 r_0} = \frac{2\pi \times 214\ 54^3}{365.256 \times 86400} = .00062565r_0$; $g_0 = v_0^2 \div r_0 = .00000039144r_0$; $\frac{t}{2} = v_\lambda \div g_0 = 1100965$ sec.; $L = 214.54r_0 \div \left(\frac{\text{half-year}}{1100965 \text{ sec.}}\right)^{\frac{2}{3}} = 36.36r_0$; $M = \left(\frac{v_\lambda}{v_0}\right)^2 r_0 = 474460r_0$.

VIII. By introducing the ratio of dissociative subsidence, (ζ), with the general equation $x_n = \xi\eta^n\zeta^{n^2}$, we find a series of paraboloidal abscissas which complete the photodynamic demonstration of a harmonic nodal action, uniting the solar, planetary and stellar systems. Take for the middle abscissa, $\frac{4}{3}$L, and for the limiting abscissas of centripetal action, $\frac{1}{6}r_0$ and $LM \div r_0$. The relative *vis viva*, or the locus of projection against uniform resistance, of the linear centre of oscillation of L, is $\frac{4}{3}$L; $\frac{1}{6}r_0$ is the paraboloidal vertex; $LM \div r_0$ bears the same ratio to M as L to r_0. If we take 18 successive abscissas on each side of the middle abscissa, the logarithms of η and ζ can be readily found by the equation:

$$\text{Log. } \xi = \text{log. } \tfrac{1}{6} = -.778151.$$
$$\text{Log. } \xi + 19 \text{ log. } \eta + 361 \text{ log. } \zeta = \text{log. } \tfrac{4}{3} L = 1.208452.$$
$$\text{Log. } \xi + 38 \text{ log. } \eta + 1444 \text{ log. } \zeta = \text{log. } LM = 7.236836.$$

Of these 39 abscissas, 9 are between the vertex and $\frac{1}{2}r_0$, the locus of solar dissociative subsidence (ζ); 9 are between $\frac{1}{2}r_0$ and L; 9 are between L and the locus of reciprocal action, which will be presently explained; 9 are between the reciprocal locus and $LM \div r_0$.

The 40th abscissa is $46353000r_0$, (log. $46353000 = 7.666079$). This is in the region of the fixed stars, and at the probable locus of *α Centauri*, the four most recent estimates of its distance ranging between $45340000r_0$ and $48479500r_0$. Both in the centripetal and centrifugal branches of paraboloidal action, 12 of the abscissas are between Sun's centre and surface; 9 are between Sun's surface and the planetary region; 9 are in the planetary region; 9 are between the planetary region and *α Centauri*.

Dividing the planetary abscissas by 214.54, in order to reduce them to terms of Earth's semi-axis major, we find the following accordances:

n.	Centripetal abscissas.	Planetary loci.		n.	Centrifugal abscissas.	Planetary loci.	
21	.2095	$\frac{1}{2}$ Mercury	.1985	—21	.2494	Mercury s. p.	.2974
22	.3632	$\frac{1}{2}$ Venus	.3617	—22	.4362	Mercury m. a.	.4555
23	.6459	$\frac{2}{3}$ Earth m. p.	.6441	—23	.7820	Venus s. a.	.7744
24	1.1788	$\frac{2}{3}$ Mars	1.1424	—24	1.4392	Mars m. p.	1.4032
25	2.2080	$\frac{4}{5}$ Asteroid 55	2.2080	—25	2.7179	Asteroid 45	2.7200
26	4.2432	$\frac{5}{6}$ Jupiter	4.3357	—26	5.2666	Jupiter	5.2028
27	8.3673	$\frac{6}{7}$ Saturn	8.1762	—27	10.4720	Saturn s. a.	10.3433
28	16.9309	$\frac{7}{8}$ Uranus	16.7857	—28	21.3662	Uranus s. a.	20.6792
29	35.1523	$\frac{7}{8}$ Neptune	35.0395	—29	44.7322	$\frac{3}{2}$ Neptune m.p.	44.5985

Both in the centripetal and in the centrifugal abscissas, Neptune indicates a reciprocal action, as if from a joint solar and stellar tendency, the solar preponderating. The centripetal co-efficient ($\frac{7}{8}$) is reciprocal to that of Saturn ($\frac{6}{7}$), Saturn's orbit embracing the primitive centre of rotating inertia for the planetary portion of the nebula ;* the centrifugal co-efficient ($\frac{3}{2}$) is the reciprocal of Earth's centripetal co-efficient ($\frac{2}{3}$).†

All the centripetal abscissas represent loci of nebular subsidence, (ζ), which would communicate velocities equivalent to the corresponding solar-stellar parabolic velocities.

All the centripetal abscissas, except Earth's, correspond most nearly with mean planetary loci ; Earth's abscissa represents mean perihelion, or the mean locus of maximum velocity, which is also the locus of belt formation (η) in a nebula extending to Earth's mean perihelion distance. This may account for the number and simplicity of the harmonic relations which I have pointed out, between Sun's mass and distance and barometric pressure, heat distribution, terrestrial magnetism, thermodynamic *vis viva*, terrestrial gravitation, æthereal and atmospheric inertia, specific gravities, explosive energies, terrestrial rotation, lunar distance, lunar revolution, planetary eccentricities, cosmical masses, nebular condensation, dissociation and aggregation, spectral lines, thermal equivalence, atomicity, chemical affinity, velocity of sound, and velocity of light.

Since these results are derived from the hypothesis of equal gravitating and æthereal action and reaction, we may infer that the density of the luminiferous æther, at Sun's surface, is $\left(\frac{r_0}{M}\right)^3$ of the Sun's density, or $\left(\frac{5.5 \times .25535}{474460^3} \times \frac{773}{.0693} =\right) \frac{1}{6821000000000}$ of the density of hydrogen.

* Proc. Am. Phil. Soc. xii, 405; xviii, 431.
† See also Ib. xviii, 231.